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R and D CENTER LABORATORY

# TECHNICAL REPORT

NO. 12665

FABRICATION OF [redacted] T142 TANK TRACK PADS FOR EVALUATION OF A RUBBER-KEVLAR COMPOSITE COMPOUND

June, 1982

CONTRACT NO. DAAE07-81-C-4073



by Clyde E. Lentz
The Standard Products Company
Port Clinton, Ohio 43452
and
Jacob Patt
U.S. Army Tank - Automotive Command
Research & Development Center

U.S. ARMY TANK-AUTOMOTIVE COMMAND
RESEARCH AND DEVELOPMENT CENTER
Warren, Michigan 48090

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

# REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
Fabrication of T142 Tank Track Pads for Evaluation of a Rubber-Kevlar Composite Compound

5. TYPE OF REPORT & PERIOD COVERED
FINAL

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)
Clyde E. Lentz

8. CONTRACT OR GRANT NUMBER(s)
DAAE07-81-C-4073

9. PERFORMING ORGANIZATION NAME AND ADDRESS
The Standard Products Company
215 Maple Street
Port Clinton, Ohio 43452

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS
U.S. Army Tank-Automotive Command
Warren, Michigan 48090

12. REPORT DATE
June, 1982

13. NUMBER OF PAGES

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

15. SECURITY CLASS. (of this report)
Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

1. Tri-Blend Compound
2. Kevlar Fiber
3. Bonding Agents
4. Composite

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A composite compound consisting of the "Tri-Blend" formulation and Kevlar fiber was developed for evaluation in T142 tank track pads. Bonding of the rubber to the fiber was achieved by addition of bonding agents to the compound. 175, T142 pads each of the "Tri-Blend" formulation and the developed composite were molded for vehicle testing. The data given shows the physical properties of these compounds.

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## INTRODUCTION

Tank track tread rubber is subjected to conditions which cause chipping and chunking as well as abrasive wear. The purpose of this project is to determine if the durability of a tank tread compound is improved by addition of aramid fibers to the rubber.

The compound selected for making the rubber-fiber composite was A-54. This compound has been previously tested in tank track treads, and has performed well.[1] A-54 compound, also known as "tri-blend", is based on a blend of natural rubber, butadiene-styrene rubber, and polybutadiene rubber. Kevlar® 29 is the aramid fiber used in the composite.

Kevlar® is a registered trademark for one member of a family of aromatic polyamide fibers manufactured by E.I. DuPont de Nemours Inc. The family as a whole has been granted the generic trade name "Aramid" by the Federal Trade Commission. Kevlar® 29 has a tensile strength of 400,000 psi (2758 M Pa) and a modulus of 9,000,000 psi (62053 M Pa). The very high tensile and modulus values that these fibers possess make them suitable for tire cords, ropes, cables, and for reinforcing plastics. Using Kevlar® fibers in tank track pads may therefore reduce chipping and chunking of the pad material. The fibers used in this study were type 970, Merge 6F107, chopped to 1/4 in. (6.35 mm.) length. The fibers were obtained from the Textile Fibers Department of DuPont.

[1] Bergstrom, E.W., "Wear Resistant Rubber Tank Track Pads", Research Directorate Report T-T-R-76-028, (Oct., 1975)

## OBJECTIVES

Before a good evaluation of a rubber - Kevlar[R] composite could be made, two problems needed to be resolved. The first of these was to learn how to obtain good dispersion of the fibers in the composite compound. The second problem was that of bonding the rubber to the fiber so as to achieve maximum reinforcement of the rubber matrix. After resolving these problems in the laboratory, the developed composite compound was mixed in the factory and molded into T-142 track pads for vehicle testing.

## CONCLUSIONS AND RECOMMENDATIONS

A composite compound consisting of the "tri-blend" formulation and Kevlar[R] fiber was successfully fabricated into T-142 pads for evaluation in tank track treads. Road testing of these pads will determine if the addition of aramid fibers to the tread compound results in better performance. Good dispersion of the fibers in the rubber was achieved, along with satisfactory bonding of the rubber to the Kevlar[R].

The additions of the fiber increased the hardness of the "tri-blend" compound by 10 to 11 points on the Shore A scale. If further work is to be done, it would seem that this hardness change should be compensated for by revision of the "tri-blend" formulation.

## EXPERIMENTAL

Dispersing Kevlar® fiber into rubber is very difficult. By experimenting with mixing procedures in a laboratory banbury mixer, good dispersion was finally achieved. A 3-pass mix with a careful order of addition of the ingredients to the mixer resulted in a well-mixed composite.

DuPont, as of this writing, does not have a sizing for Kevlar® that is capable of bonding the rubber to the fibers. This meant that the "tri-blend" formulation had to be modified slightly to achieve bonding. Bonding agents are employed in tire compounds to improve the rubber-to-fiber bond. Several of these were investigated for this application.

Bonding agents R-6 and M-3 were found to give the best results. These two products, manufactured by Uniroyal Chemical, react to form an in situ adhesive during vulcanization of the rubber. Experiments showed that 3 parts of Bonding Agent R-6 and 1.5 parts of Bonding Agent M-3 was sufficient amounts to provide maximum bonding. These amounts are parts per 100 Rubber (PHR) by weight. Data on these bonding agents is given in the appendix.

Laboratory mixes were made with varied amounts of Kevlar® added to the "tri-blend" compound. Standard 6 in. X 6 in. slabs of these composites were vulcanized and tested for tensile strength, modulus and hardness. Using these results as criteria, it was decided to use 5 PHR by weight Kevlar® in the composite. Table 1 shows the three compounds used in this study. Compound 1 is the "tri-blend", compound 2 is the "tri-blend" composite, and compound 3 is the composite with bonding agents added.

Mixing of the factory batches was done in a Farrel #11 Banbury Mixer. The "tri-blend" compound was mixed using 2 passes, while a 3-pass mix was used for the composite. The rubber was then extruded and molded into T-142 tank track pads. A cure of 75 minutes at 320°F was used. 175 pads of each compound were compression molded for vehicle testing. No problems were encountered in processing either compound.

# RESULTS AND DISCUSSION

The stress-strain plots of the compounds used in this study are shown in Figures 1 and 2. The molded tensile slabs were tested both in the direction of milling and also in the transverse direction. A comparison of the curves for the composite compounds shows a large difference in stress-strain properties when pulled in the two directions. This is because milling the rubber prior to molding the tensile slabs orients the fibers. Orientation of the fibers in the molded track pads would not be as great since there is much more flow of the compound in the pad mold than there is in the tensile slab mold. The stress-strain properties for the "tri-blend" compound are nearly the same for either direction of pull.

Additional test data for these compounds are shown in Table 2. It can be seen that the tensile strength of the composite compounds is actually less than for the "tri-blend". The modulus values, especially at very low strain, are higher for the composite compounds. Modulus of the composite compound is raised by the addition of bonding agents. This is an indication of the rubber being bonded to the fiber with an increase in reinforcement. The elongation of the "tri-blend" is reduced by fiber addition, while room temperature tear-strength remains about the same. Hot tear at 250°F is superior for the composite compounds. The Shore A durometer rating is increased significantly by adding Kevlar$^R$ to the "tri-blend".

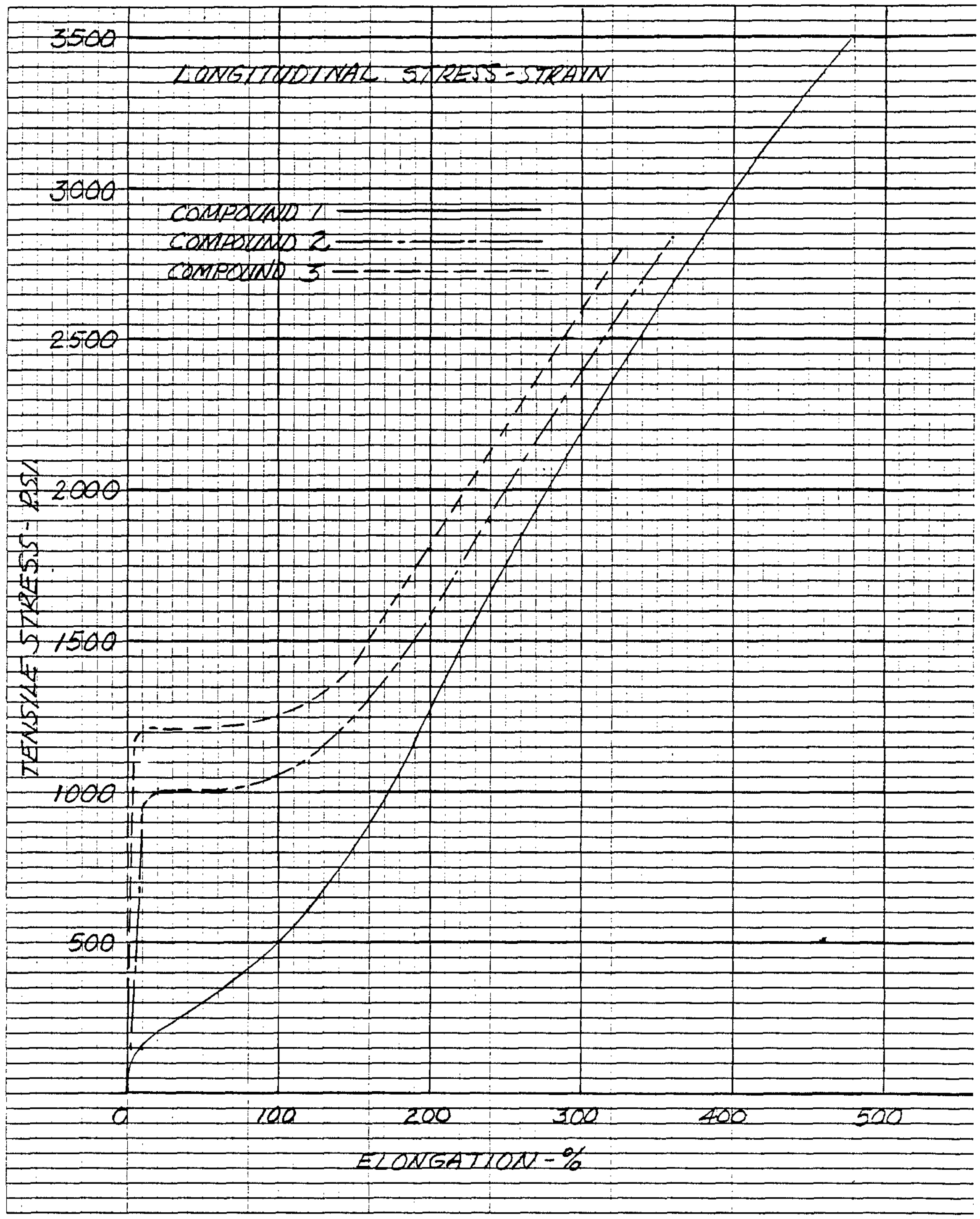


Figure 1. Stress-Strain Curves of Experimental Compounds pulled in Direction of Milling.

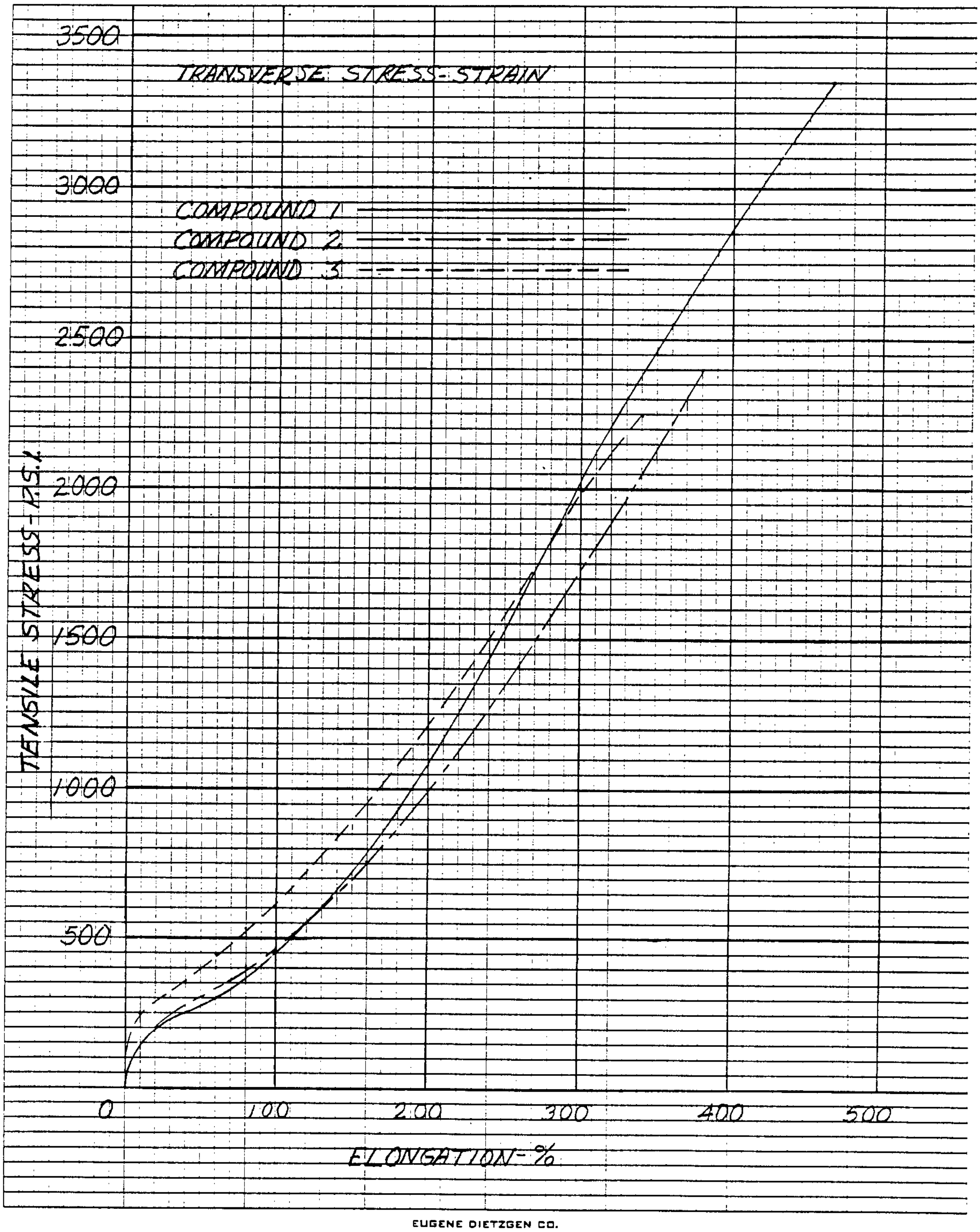


Figure 2. Stress-Strain Curves of Experimental Compounds Pulled Transverse to Direction of Milling.

TABLE 1 EXPERIMENTAL COMPOUNDS

| C. I. | 1 | 2 | 3 |
|---|---|---|---|
| Philprene 1609 | 40.6 | 40.6 | 40.6 |
| Cis-4 1203 * | 12.0 | 12.0 | 12.0 |
| Pale Crepe | 60.0 | 60.0 | 60.0 |
| SAF Black (N110) | 42.0 | 42.0 | 42.0 |
| ISAF Black (N220) * | 9.6 | 9.6 | 9.6 |
| Zinc Oxide | 3.0 | 3.0 | 3.0 |
| Stearic Acid | 2.0 | 2.0 | 2.0 |
| Sulfur | 2.0 | 2.0 | 2.0 |
| Santocure | 1.5 | 1.5 | 1.5 |
| Agerite Superflex Solid G † | 1.0 | 1.0 | 1.0 |
| Santoflex AW | 1.5 | 1.5 | 1.5 |
| Piccopale 100 | 3.5 | 3.5 | 3.5 |
| U.O.P. 88 | 5.0 | 5.0 | 5.0 |
| Sunolite 240 Wax ‡ | 1.0 | 1.0 | 1.0 |
| Philrich 5 * | 4.2 | 4.2 | 4.2 |
| 1/4" Kevlar | | 5.0 | 5.0 |
| Bonding Agent R-6 | | | 3.0 |
| Bonding Agent M-3 | | | 1.5 |
| | 188.9 | 193.9 | 198.4 |

* These ingredients substituted for Cis-4 1350 used in original formulation.

† This ingredient was substituted for discontinued Thermoflex A used in original formulation.

‡ This ingredient was substituted for discontinued Heliozone Wax used in original formulation.

TABLE 2. PHYSICAL PROPERTIES OF EXPERIMENTAL COMPOUNDS

Specimens from 6" X 6" molded slabs cured 30 min @ 298° F

| Physical Properties - Tested Longitudinally | Comp. 1 | Comp. 2 | Comp. 3 |
|---|---|---|---|
| Tested at ambient: | | | |
| Tensile, PSI (MPa) | 3500 (24.14) | 2840 (19.58) | 2760 (19.03) |
| Modulus @ 100%, PSI (MPa) | 500 ( 3.45) | 1050 ( 7.24) | 1250 ( 8.62) |
| Modulus @ 200%, PSI (MPa) | 1275 ( 8.79) | 1575 (10.86) | 1780 (12.27) |
| Modulus @ 300%, PSI (MPa) | 1975 (13.62) | 2400 (16.55) | 2600 (17.93) |
| Modulus @ 400%, PSI (MPa) | 2950 (20.34) | - | - |
| Ultimate Elongation | 480 | 360 | 325 |
| Hardness, Shore A | 70 | 80 | 81 |
| Tear, Die B, ambient, lb/in (kN/m) | 558 (97.72) | 539 (94.39) | 515 (90.19) |
| Tear, Die B, at 250° F, lb/in (kN/m) | 262 (45.88) | 363 (63.57) | 333 (58.32) |
| Oven Aged 70 hrs. @ 158° F (70° C) | | | |
| Tensile, PSI (MPa) | 3360 (23.17) | 3060 (21.10) | 2800 (19.30) |
| Modulus @ 100%, PSI (MPa) | 625 ( 4.31) | 1225 ( 8.45) | 1375 ( 9.48) |
| Modulus @ 200%, PSI (MPa) | 1575 (10.86) | 1850 (12.75) | 2075 (14.31) |
| Modulus @ 300%, PSI (MPa) | 2575 (17.75) | 2750 (18.96) | - |
| Modulus @ 400%, PSI (MPa) | 3360 (23.17) | - | - |
| Ultimate Elongation, % | 400 | 330 | 290 |
| Hardness, Shore A | 74 | 83 | 86 |
| Ozone Resistance @ 100° F (37.8° C) | | | |
| 7 days, 50 pphm Bent Loop Specimen | Crack Free | Crack Free | Crack Free |
| Brittleness Test at -40° F (-40° C) | Passed | Passed | Passed |
| Compression Set Method B | | | |
| 22 hrs @ 158° F (70° C) | 21.5% | 28.0% | 28.5% |

APPENDIX A

DATA SHEET FOR BONDING AGENTS

UNIROYAL CHEMICAL
Division of UNIROYAL, Inc.
Naugatuck, Connecticut 06770

# Naugatuck® Chemicals

## BONDING AGENTS

### Adhesive Systems for Rubber and Fiber Bonding

| | Bonding Agent R-6* | Bonding Agent M-3* |
|---|---|---|
| Chemical Description | Resorcinol Donor | Methylene Donor |
| Typical Physical Properties | | |
| Form | Powder | Flake |
| Specific Gravity | 1.32 | 1.422 |
| Melting Point | 81-99°C | 55°C |
| Storage Stability | Good-store in cool dry place | Good-Hydroscopic-store in cool dry place |
| Solubility | Sol. in acetone, MEK Sl. Sol. in water Insol. in benzene, toluene, and n-hexane | Sol. in water, alcohol, benzene and n-hexane |

**Handling Precautions:**

Normal handling precautions for organic chemicals are recommended. Laboratory toxicity tests indicate no unusual problem. This has been confirmed by commercial experience. Handling precautions with R-6 should be the same as other resorcinol derivatives.

**Recommended Use:**

In rubber compounds for improved adhesion, particularly to cotton, rayon nylon, polyester, glass, and wire.

**Amounts to Use:** – Tire Application

Bonding Agent M-3 – 1 to 1.5 parts per 100 RHC together with
Bonding Agent R-6 – 2 to 3 parts per 100 RHC

Nitrile and chloroprene rubbers – Mechanical Goods and Hose

Bonding Agent M-3 – 1 to 1.5 parts per 100 RHC
Bonding Agent R-6 – 2 to 3 parts per 100 RHC

**Compounding:**

| | |
|---|---|
| Effect on Rate of cure | slight retardation of cure |
| Staining | none |
| Discoloration | slight |
| Processing | as outlined |
| Bloom | none |

*The use of these bonding agents is covered by one or more of the following U.S. Patents: 3,266,970; 3,281,311; 3,256,137.

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## FIBER TO RUBBER ADHESION

Since the 1930's, resorcinol-formaldehyde-latex (RFL) compositions have been used as primary adhesives to bond textile materials to rubber compounds. The principal application of this system has been the carcass of a tire.

The demands for durability and safety placed on all types of tires have steadily increased. Automobiles can cruise for hours at 65-75 miles per hour on expressways and turnpikes while off-the-road vehicles can attain speeds as high as 40 miles per hour while carrying tremendous loads.

Textile developments kept pace with the increasing demands on tires during this time by developing new and stronger fibers. Rayon replaced cotton and then nylon was introduced. In recent years, polyester, glass, and steel wire have been used for carcasses in tires. As fiber strength improvements were made, improvements in adhesives were also required. These new synthetic fibers were more difficult to bond to rubber and required the development of new latices such as PYRATEX.®

Although the overall quality of tires has improved substantially during this period, tread and ply separations continue to be a problem, especially at high speed operation. Other problems in fiber to rubber adhesion have also arisen in non-tire applications such as high angle V-trough conveyor belting. The Bonding Agent system was developed to provide a solution to these problems.

The Bonding Agent system is used to increase the cured adhesion bond between the rubber compound and textile fibre over and above the adhesive bond provided by the RFL dip. Just as the resorcinol-formaldehyde in the dip forms a resinous adhesive to improve the bond strength, so the bonding agents form an in situ adhesive in the carcass compound to supplement and link to the dip adhesive, thereby further improving total adhesion.

The addition of these chemicals to tire skimcoat stocks has been particularly effective in raising tire cord adhesion and reducing ply and tread separations. This system can also be applied to belts, diaphragm valves, printing blankets, high pressure wire-reinforced hose and any product involving rubber to fabric or wire adhesion. The system has also been effective in improving bond strength at rubber to rubber interfaces and can be added to stocks used for cements.

In the new bias-belted and radial ply tire construction, the cut edges of the belt are not treated. Since greige (untreated) cord adhesion is increased with compounds using the Bonding Agent systems, its application in belt compounds should improve the separation resistance at the belt edges.

## THE ADHESIVE SYSTEM

The improved adhesive bond is the result of the in situ reaction of resorcinol or a resorcinol derivative with a methylene donor in compounded stocks to give an adhesive resin. Although resorcinol is the basic chemical to use, it has undesirable fuming properties at Banbury mixing and calendering temperatures. These fumes can be irritating if there is inadequate ventilation at the mixing operation. Bonding Agent R-6 is a resorcinol reaction product which can be substituted for resorcinol to minimize this fuming problem. Bonding Agent M-3 is the other half of the resin forming reaction. It provides the crosslinking agent to react with Bonding Agent R-6 to form the adhesive system.

## MIXING PROCEDURE

Since the reaction between the two Bonding Agents goes rapidly at elevated temperatures, it is advisable to use a two stage mixing procedure. Bonding Agent R-6 is added to a carbon black masterbatch or other premix, without accelerators. Discharge or mixing temperature should reach 220°F as a minimum in order to dissolve or disperse the resorcinol component.

Bonding Agent M-3 is then added, with the accelerators, in the final mix, with temperatures not to exceed 230°F. The adhesive reaction will then take place in the final cure of the product.

If convenient, masterbatches of Bonding Agent R-6 may be made in natural rubber, SBR, BR, IR, or Nitrile.

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Note: This Bonding Agent system has not yet been fully developed with highly saturated rubbers such as butyl or ROYALENE® (EPDM)